

DESCRIPTION

DRIVING METHOD OF DISPLAY APPARATUS

5 [TECHNICAL FIELD]

The present invention relates to a driving method of a display device capable of displaying an image by controlling distribution of electrophoretic particles (charged particles) and capable of effecting
10 writing of an additional handwritten image such as a line image or a character image to an image, such as a gradation image.

[BACKGROUND ART]

15 With development of information equipment, the needs for low-power and thin display apparatuses have grown, so that extensive study and development have been made on display apparatus fitted to these needs. Such display apparatuses includes a display
20 device which permits handwriting input of graphic and character images while effecting pressing with a pen (stylus) or finger without using a keyboard (hereinafter, this function is referred to as a "pen input function") in view of use in outdoors, power
25 saving and spacing saving. This display device is used in a wearable PC (personal computer), an electronic note pad, etc.

BEST AVAILABLE COPY

A liquid crystal display device is known as the display device but has been accompanied with problems when it is provided with a pen input function. More specifically, most of liquid crystals have no memory characteristic, so that it is necessary to continuously apply a voltage during display (input of graphic or characters), thus resulting in an increase in power consumption. On the other hand, with respect to liquid crystals having a memory characteristic, it is difficult to ensure reliability on the assumption that the resultant liquid crystal device is used in various environments as in the wearable PC. As a result, it is difficult to commercialize the liquid crystal device.

As another type of a display apparatus having a memory characteristic and of a low-power and thin type, an electrophoretic display apparatus has been proposed by Harold D. Lee et al. (U.S. Patent No. 3,612,758).

This type of electrophoretic display apparatus includes a pair of substrates disposed with a predetermined spacing, an insulating liquid filled in the spacing between the substrates, a multiplicity of colored charged migration particles (electrophoretic particles) dispersed in the insulating liquid, and an upper electrode (disposed on a viewer side substrate) and a lower electrode

(disposed on a rear substrate) which are disposed along the respective substrates at each pixel. The electrophoretic particles are electrically charged positively or negatively, so that they are adsorbed by the upper electrode or the lower electrode depending on a polarity of a voltage applied to these electrodes. As a result, it is possible to display an image by utilizing a state in which the electrophoretic particles are adsorbed by the upper electrode and are observed from a viewer side and a state in which the electrophoretic particles are adsorbed by the lower electrode so that the color of the insulating liquid is visually identified. This type of the electrophoretic display apparatus is referred to as a vertical movement type electrophoretic display apparatus.

On the other hand, Japanese Laid-Open Patent Application (JP-A) No. Hei 9-211499 has disclosed a horizontal movement type electrophoretic display apparatus. This type of electrophoretic display apparatus, different from the vertical movement type electrophoretic display apparatus including the upper and lower electrodes disposed to sandwiched the insulating liquid, includes electrodes 13a and 13b which are disposed along one substrate 10b so as to move electrophoretic particle 12 in a direction along the substrate 10b as described in detail later with

reference to Figure 6. In the horizontal movement type electrophoretic display apparatus displays an image by utilizing a difference in color between a dispersion state of the electrophoretic particles in a broad area and an accumulation (collection) state of the electrophoretic particles in a narrow area while using a transparent insulating liquid 11.

As a device capable of inputting graphics and characters while applying pressure with a pen or finger. JP-A Hei 5-324163 has proposed a resistance film type coordinate position detection device. By using the electrophoretic display apparatus and such a detection device in combination, it becomes possible to realize a paper like display which, e.g., permits the wearable PC of power and space saving type and can take notes.

In a conventional display device having the pen input function, when pen input is performed, a position coordinate of the pen is detected and written over an image which has already been stored in a display memory. Thereafter, similarly as in ordinary display, data is read from the display memory frame by frame and is sent to a display panel. As a result, the image overwritten with the pen is displayed on a display picture area (screen).

Incidentally, an ordinary electrophoretic display apparatus having no pen input function, such a

driving method wherein a reset drive is performed before effecting an image writing drive has generally been used. More specifically, a display state is once reset to white or black. This is because it is
5 necessary to erase a previously displayed image in order to display a fresh image since the electrophoretic display apparatus has a memory characteristic. The rewriting with resetting includes a case where it is performed by separating reset
10 scanning and writing scanning on a field basis and a case where it is performed by continuously effecting resetting and writing on a line basis.

The electrophoretic display (apparatus) has a relatively slow display response to voltage
15 application when compared with CRTs (cathode-ray tubes) and liquid crystal displays, so that it is used principally for displaying still image, e.g., in electronic book or previous display. For these purposes, the entire picture area is ordinarily
20 rewritten on a page basis, so that a resultant image can be viewed with less inconformity even when the picture area is once reset to pure white or solid black.

However, even for the purpose of still image
25 display, at the time of pen-based input, rewriting operation frequently occurs in order to reproduce a trail of a pen as fast as possible. If the frequency

of rewriting operation is low, the trail of the pen is displayed late on the picture area even when the pen is moved on the picture area, so that a user feels a considerable inconformity. Accordingly, the display apparatus is required to have a moving image-level rewriting frequency at the time of pen input.

However, in the case of performing the above-described driving method using the reset drive and the writing drive, the reset state is visually identified flickeringly. As a result, a display quality is lowered. This flickering is particularly noticeable in the electrophoretic display since it has a low response speed. Even if a so-called partial rewriting operation for scanning only a rewritten portion is performed in order to promote reflectance of the pen input in display, it is no difference from the fact that the reset state is visible to eyes.

Further, when the position coordinate of the pen input is overwritten in a display memory, information on the trail of the pen is stored partially, i.e., so-called on a piecemeal basis, in a certain rewriting cycle since the rewriting cycle of the display memory is previously determined. Accordingly, a display of the pen trail is also performed on a piecemeal basis, so that a line or a character inputted with the pen is not displayed as the pen is moved. The user also feels inconformity

with respect to this phenomenon.

In some cases, such an "undo" function that only an additional image written with a pen or the like is erased so that the display state is returned
5 to a previous state before writing of the additional image is added to the display apparatus, but when a reset drive is performed in such cases, flickering is caused to occur, thus lowering a display quality.

10 [DISCLOSURE OF THE INVENTION]

An object of the present invention is to provide a driving method of an electrophoretic display apparatus which alleviates a lowering in display quality and inconformity felt by a user in the case of
15 effecting pen-based input as described above.

Another object of the present invention is to provide such an electrophoretic display apparatus.

According to the present invention, there is provided a driving method of a display apparatus,
20 comprising:

a first drawing step of displaying an image by controlling a display medium on the basis of a signal from first image creation means, and
a second drawing step of overwriting a
25 handwritten image, such as an additional line or character image on the displayed image by controlling the display medium on the basis of a signal from

second image display means,

wherein in the first drawing step, an image is rewritten by a reset drive for resetting a display state and a writing drive for writing an image, and in
5 the second drawing step, the writing drive is performed without effecting the reset drive.

According to the present invention, there is also provided a display apparatus, which permits handwriting input and has a memory characteristic,
10 comprising:

detection means for detecting handwriting input, and

drive means for effecting a first drive in which an image is rewritten by applying a writing
15 voltage after resetting a previous display image when the handwriting input is not detected, and a second drive in which a previous display image is overwritten with a handwriting image by applying only a writing voltage without effecting resetting when the
20 handwriting input is detected.

By the driving method of electrophoretic display apparatus of the present invention, in the second drawing step, the writing drive is performed but substantially no reset drive is performed, so that
25 a handwritten image (e.g., an additionally written line or character image) is displayed of good quality without causing a broken image.

Further, in the case of effecting a drive for erasing an additional image while leaving only a gradation image, no flickering or the like is not caused to occur. As a result, it is possible to avoid
5 a lowering in display quality.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Figure 1 is a waveform diagram for explaining the driving method of an electrophoretic display
10 apparatus according to the present invention.

Figure 2 is a waveform diagram for explaining an embodiment of a first drawing step.

Figure 3 is a block diagram showing a structure of the electrophoretic display apparatus of
15 the present invention.

Figure 4 is a block diagram showing a detailed structure of the electrophoretic display apparatus of the present invention.

Figure 5 is a circuit diagram showing a
20 structure of an electrophoretic display panel.

Figure 6(a) and 6(b) are respectively a sectional view of an electrophoretic display device.

Figure 7 is a graph showing an embodiment of a voltage-optical response (reflectance)
25 characteristic of the electrophoretic display device.

Figure 8 is a graph showing a previous state dependence of an electrophoretic display apparatus.

Figures 9, 10 and 11 are respectively a waveform diagram for explaining another embodiment of the driving method of electrophoretic display apparatus of the present invention.

5

[BEST MODE FOR CARRYING OUT THE INVENTION]

Figure 3 is a schematic view of the display apparatus according to the present invention.

Referring to Figure 3, a display panel 1
10 receives display image data from both of a first image creation means 2 and a second image creation means 3 and effects display through a control unit (controller) 4.

Figure 4 is a block diagram showing a
15 detailed structure of respective structural members shown in Figure 3.

The display panel 1 constitutes a display module 47 together with a TFT (thin film transistor) backplane 46, a scanning line drive circuit 15, and a
20 data line drive circuit 16.

The first image creation means 2 is a circuit block having a function of displaying a previously memorized image or an externally given image on the display panel (display device) 1. As shown in Figure
25 4, the circuit block includes an internal memory for storing an image (SRAM) 201, an external memory (flash ROM) 202, a communication interface circuit 203 which

receives an external image signal, and a buffer circuit 200 for transmitting these signals to the controller 4.

5 The second image creation means 3 is a circuit block having a function of displaying a pen input image drawn by a user on the display panel 1. The circuit block includes a digitizer 31 (comprising X-coordinate detection sheet 31x and Y-coordinate detection sheet 31y) for detecting a position pressed
10 with a pen (stylus) or finger, a memory 33 for storing a signal from the digitizer 31, and a digitizer controller 32 for outputting the memorized coordinate position as an image signal.

 The controller 4 includes a panel controller
15 400, a graphic controller 401, a CPU 403, a power management 404, an external memory control circuit 405, etc.

 The graphic controller feeds information to be displayed on the display panel 1 on the basis of
20 information preliminarily stored in the internal memory 201 and those on, e.g., the coordinate position sent from the external memory 202, the communication interface circuit 203 or the digitizer controller 32, to a video RAM (VRAM) 5, and transfers image data and
25 control signals in formats required for driving the display panel 1 on the basis of information in the VRAM 5 to the display module 47 through the panel

controller 400.

In the display module 47, the image data outputted from the panel controller 400 and the control signals such as Vsync and Hsync are received, and desired voltages are applied from the scanning line drive circuit 15 and the data line drive circuit 16 to the TFT backplane 48 to effect display at each pixel of the display panel 1.

As described later in detail, this type of electrophoretic display apparatus not only can display a pen-based input image, such as a handwritten character, on the display panel based on information obtained from the second image creation means 3 but also can overwrite a displayed gradation image with a line, character or the like obtained from the second image creation means 3 by displaying the gradation image on the display panel based on information stored in advance in the first image creation means 2.

As the display panel 1, an electrophoretic display panel having an active matrix structure is representatively used.

Figure 5 illustrates a schematic view of the display panel 1 and the drive circuit blocks 15 and 16 disposed at a periphery of the display panel 1. The display panel 1 includes, as will be described later, two substrates 10a and 10b (Figures 6(a) and 6(b)) of which the substrate 10b is provided with gate

signal lines g1, g2, ..., and source signal lines s1, s2, ..., which intersect at right angles and further provided with a TFT 14 (as a switching element) and a pixel electrode 13a at an intersection of the gate and source signal lines. Each of the TFT 14 has a gate electrode connected to an associated gate signal line g1, g2, ..., a source electrode connected to an associated source signal line s1, s2, ..., and a drain electrode connected to the pixel electrode 13.

At the periphery of the electrophoretic display panel 1, the scanning line drive circuit (scanning driver) 15 for driving the gate signal lines and the data signal line drive circuit (data driver) 16 for driving the source signal lines. The scanning driver 15 is connected to the gate electrodes g1, g2, ..., and the data driver 16 is connected to the source electrodes s1, s2, ...

A representative structure of the electrophoretic display device is shown in Figures 6(a) and 6(b).

The display panel 1 is constituted by two-dimensionally arranging a plurality of electrophoretic display devices 9 each shown in Figure 6 in a state shown in Figure 5.

As shown in Figures 6(a) and 6(b), the electrophoretic display device 9 includes a pair of substrates 10a and 10b disposed with a spacing and

electrophoretic particles 12 and an insulating liquid 11 which are filled in the spacing. On one substrate 10b, an electrode 13 is disposed at each pixel and is connected to the switching element 14 (not shown in Figure 6 but shown in Figure 5). At a pixel boundary portion, a common electrode 13b is disposed. By applying an electric field between the pixel electrode 13a and the common electrode 13b, the electrophoretic particles 12 are moved between a visually black (dark) state due to the color of the electrophoretic particles (Figure 6(a)) and a visually white (bright) state due to light reflected from the substrate, thus being placed in a dark or bright display state.

A voltage-optical response (reflectance) characteristic of the electrophoretic display device 9 is shown in Figure 7, which shows a characteristic of a display device having a memory characteristic. Referring to Figure 7, when the electrophoretic particles are placed in the darkest state under no voltage application (at 0 V), this state is not changed under application of a positive-polarity voltage but is changed to a bright state at a certain voltage of a negative polarity. Even when the applied voltage is returned to 0 V after the display state is changed to the bright state, the resultant state is not returned to the darkest state but is kept in the bright state. This characteristic is the memory

characteristic. When a position-polarity voltage is applied to the device in the bright state, the display state is changed to the dark state. Thereafter, when the applied voltage is returned to 0 V, the dark state is retained.

Figure 8 is a graph showing a previous (display) state of the electrophoretic display apparatus. More specifically, Figure 8 illustrates a relationship between a previous state reflectance and a writing voltage required for displaying predetermined gradation levels (i.e., 0/4 gradation, 1/4 gradation, 2/4 gradation, 3/4 gradation, and 4/4 gradation). Figure 8 shows that the writing voltage should be changed depending on a previous state reflectance even when an identical gradation level is intended to be displayed, i.e., that a different reflectance is obtained even if an identical voltage is applied. From the results shown in Figure 8, it is understood that it is necessary to keep the previous state reflectance at a constant value by the reset drive so as not to change the relationship between the writing gradation level and the writing voltage. Accordingly, in this embodiment, in a first drawing step for displaying a fresh image, the reset drive is performed.

(First Embodiment)

Figure 1 is a drive waveform used in this

embodiment according to the driving method of electrophoretic display apparatus of the present invention.

Figure 1 shows a gate voltage at each pixel (a voltage applied to a gate electrode disposed at each pixel) at (a), a source voltage in an "area 1" shown at (h) (a voltage applied to a source electrode disposed at a pixel corresponding to the "area 1") at (b), a corresponding drain voltage (a voltage applied to the pixel electrode 13a) at (c), an optical response in the "area 1" at (d), corresponding voltages or optical response in an "area 2", shown at (h), at (e) to (d), and a display image at (h).

The display apparatus of the present invention effects display by using a driving method including separated three steps different in driving (operation) manners.

(1) First drawing step

In this step, image display is performed by a signal from the first image creation means 2. This drawing step is performed in a period from a time t_0 to a time t_1 shown at (h) of Figure 1. When rewriting of display is effected, resetting is performed prior to writing of a fresh image.

(2) Memory display step

In this step, the finally written image is retained by a memory characteristic of the display

panel. This memory display step is performed in a period from the time t1 to a time t2 shown at (h). A signal input is terminated at the time t1 and the display state at the time t1 is maintained during the period from the time t1 to that time t2.

(3) Second drawing step

In this step, an image is drawn on the display panel with the use of the digitizer 31 and a dedicated pen (stylus) 34, or the displayed image is overwritten with a line or a character. This second drawing step is performed in a period of the time t2 or later.

Drive in the first drawing step (1) will be described more specifically.

In the first drawing step, an image signal 21 and a clock (CLK) signal 22 are inputted from the first image creation means 2 to the controller 4 through signal lines 21 and 22. In the controller 4, an image correction such as γ correction is made with respect to the inputted image signal 21. For example, when each color information is 8 bits, 24 bit image data 41 corresponding to red, green and blue (8 bits x 3) at each pixel is serially outputted successively. Further, on the basis of the inputted CLK signal 22, a synchronizing signal V-sync 42 is produced and outputted to the electrophoretic display panel 1. The inputted signal 21 is sent to the

digitizer controller 22 as it is, as an output 320.

In the electrophoretic display panel 1, a drive waveform based on the serial image data and the synchronizing signal V-sync inputted from the input terminals 41 and 42 is outputted from the scanning drive 15 and the data driver 16, thus applying a gate voltage and a source voltage to the TFT 14 at each pixel.

Figure 2 is a time chart showing timing of voltage application in the first drawing step, wherein (a) shows a scanning signal voltage (gate voltage), (b) shows a data signal voltage (source voltage), (c) shows a drawing voltage, and (d) shows an optical response at an associated pixel.

One frame period F_m ($m = 1, 2, 3, \dots$) is divided into two field periods including a former field period $F_{m, 1}$ and a latter field period $F_{m, 2}$. In the respective former field periods $F_{m, 1}, F_{m+1, 1}, \dots$, image resetting is performed, and in the respective later field periods $F_{m, 2}, F_{m+1, 2}, \dots$, image writing is performed.

In a specific example, the gate voltage has an ON voltage of +20 V, and OFF voltage of -20 V, and a frame rate of 15 Hz (at (1) of Figure 2). Further, the source voltage has a reset voltage of +15 V and a writing voltage which can be changed in a range of 0 V to -15 V (at (b) of Figure 2). The common electrode

voltage is substantially 0 V. However, even when the source voltage is 0 V, in most cases, the drawing voltage does not become 0 V by the influence of feed through, so that the common electrode voltage is
5 adjusted so as not to cause a potential difference between the pixel electrode and the common electrode when the source voltage is 0 V.

Figure 2(c) shows a drain electrode potential, i.e., a pixel electrode potential.

10 In reset periods (the former field periods $F_m, 1, F_{m+1}, 1, \dots$), a voltage of -15 V is applied to the drain electrode through the source electrode, and the common voltage is 0 V, so that the electrophoretic particles at an associated pixel are attracted toward
15 the common electrode 13b side. As a result, while writing is performed and the pixel is placed in a reset state as shown in Figure 6(b).

In writing periods (the latter field periods $F_m, 2, F_{m+1}, 2, \dots$), a writing voltage (a voltage in
20 the range of 0 to -15 V) is applied to the drain electrode through the source electrode, and the common voltage is 0 V, so that the electrophoretic particles at an associated pixel are attracted toward the pixel electrode 13a side. As a result, the pixel is placed
25 in a state shown in Figure 6(a) or an intermediary state between the states shown in Figures 6(a) and 6(b).

In the first drawing step, the above-described driving is performed, so that on the electrophoretic display panel, as shown in Figure 1(h), the display is performed in the following manner.

In the reset period $F_n, 1$, the entire white display is performed. In the subsequent writing period $F_n, 2$, a picture of a house is displayed. In the subsequent reset period $F_{n+1}, 1$, the entire white display is performed. In the subsequent writing period $F_{n+1}, 2$, a picture of a flower is displayed.

Next, the drive in the above-described memory display step (2) will be described.

When the signal input from the first image creation means 2 to the controller 4 is terminated in such a state that the picture of flower is displayed at the end of the period from t_0 to t_1 , the source voltage becomes 0 V (Figures 1(b) and 1(e)). As a result, the display device is not supplied with a voltage to retain the display state as it is. In other words, memory display is performed.

Next, the drive in the above-described second drawing step (3) will be described.

In the case where the pen input is effected, the X-axis position detection sheet 31x and the Y-axis position detection sheet 31y of the digitizer 31 contact each other to effect position detection of X

axis and Y axis of a certain point pressed with a pen
by the coordinate position detection unit. The
digitizer 31 effects detection of coordinate position
plural times within one frame period on the basis of
5 sampling period formed based on the CLK signal
inputted from the input terminal 320, so that the data
of movement of the pen written one frame period is
stored in the memory 33 in the digitizer controller
32. The pen input coordinate positioned detection
10 data is outputted to the controller 4 on the basis of
the inputted V-sync signal.

The controller 4 receives the V-sync signal
and reads out the finally outputted image data stored
in the graphic memory 5. The controller 4 further
15 combines and outputs the pen input coordinate position
detection data and the image data read from the
graphic memory, whereby the image data overwritten
with the image drawn by the pen input is displayed on
the display panel.

20 The image data stored in the graphic memory
5 are successively read and sent to the controller 4.
The controller 4 compares the coordinate position of
the read image data with the pen input coordinate
position sent from the memory 33. In the case where
25 these positions are coincident with each other, the
image data of the coordinate position is sent to the
display panel as a darkest luminance level. In the

case where these positions are not coincident with each other, the previous (original) image data is sent to the display panel as it is. The darkest luminance level is used for displaying a picture or character drawn with the pen as a black line image.

As described above, when the pen input is effected, its coordinate position is once stored in the memory 33 in the digitizer 3. This writing period in the memory is several times as short as the frame period, so that the trail of the pen is stored substantially without delay. As described above, for display, the data stored in the memory 33 in the digitizer 3 is compared with the contents of the graphic memory 5 and is directly sent to the display panel. Accordingly, the trail of the pen is continuously displayed on the display panel.

In the second drawing step, the display panel is driven only by the writing drive without the reset drive. At a pixel where the pen input is not performed, a previous (original) image is written as it is, so that it is not necessary to erase the previous image. As a result, the reset drive is not required. At the pixel where the pen input is formed, the darkest state is displayed irrespective of the previous image, so that it is not necessary to effect the reset drive.

The controller 4 performs the above described

overwriting of image when the pen input coordinate position detection data and at the same time, outputs a selection signal 41 for effecting the second drawing step to be sent to the display panel 1. The display
5 panel 1 switches the driving conditions at each pixel from those for the reset/writing drive to those only for the writing drive on the basis of the inputted selection signal 43.

Based on the selection signal 43, the serial
10 image data inputted from the input terminals 41 and 42, and the synchronizing signal V-sync, a drive waveform with no reset signal is outputted from the scanning signal (gate) line driver 15 and the data signal (source) line driver 16. As a result, the pen-
15 based inputted line or character is displayed on the display panel.

The period of the time t_2 or later shown in Figure 1 represents the period in which the second drawing step is performed by the display panel 1 after
20 receiving the selection signal 43. The "area 1" represents a pixel at which overwriting is performed by effecting the pen input. Figure 1 shows a source voltage at (b), a drain voltage at (c), and an optical response (d) at the pixel. The "area 2" represents a
25 pixel at which overwriting is not performed since the reset drive is not performed. Figure 1 shows a source voltage at (e), a drain voltage (f), and an optical

response at (g) at the pixel.

In the "area 1", the source voltage is set to -15 V and the darkest luminance level voltage is applied to the pixel electrode, so that the resultant optical response is on the darkest level. In the "area 2", the source voltage is set to a value which equals to a voltage value of the image data finally written in the field period $f_{n+1, 2}$, so that the image is reproduced. In either area, the reset drive is not performed, so that the same writing drive is performed in the former and latter of the frame period.

At the time t_2 or later shown at (h) of Figure 1, such a state that the previous image is gradually overwritten with the pen-written image as a black line image to be displayed. With each passing frame period, an additional character "A" is gradually written with time.

According to the above-described driving method, at the time of pen-based input writing, it becomes possible to effect continuous image writing without effecting reset scanning. As a result, it is possible to eliminate informity occurring at the time of effecting resetting every writing.

Incidentally, in this embodiment, in order to improve simplicity and tracking with respect to pen-based input, a frame frequency during the pen input (i.e., in the second drawing step) is two times that

during an ordinary drive (i.e., in the first drawing step). However, there is no problem even if the frame frequency at the time of pen input may be constant and equal to that at the time of ordinary drive.

5 In this embodiment, only writing by pen input for effecting black drawing is described but it is also possible to effect pen input for effecting while input. Accordingly, by the pen input, it is possible to draw the black line or the white line. If the
10 intended image is a two-valued output image, it is possible to effect negative/positive inversion, full-screen black rewriting and full-screen white rewriting without effecting resetting.

 As the digitizer used in this embodiment, a
15 resistance film-type device is used but it is also possible to select and use those of an ultrasonic wave-type, electromagnetic induction-type, etc., which are suitable for use in a display device or apparatus having a memory characteristic.

20 (Second Embodiment)

 In this embodiment, the display apparatus is driven in the same manner as in First Embodiment except that the second drawing step (3) is performed by rewriting only a pen input area (pixel) to black
25 and a voltage is not applied to other pixels.

 Figure 9 shows a drive waveform in this embodiment.

Figures 9(a) to (h) correspond to Figures 1(a) to (h), respectively, illustrating respective voltage pulses and optical response, wherein identical signs represent identical meanings.

5 Similarly as in First Embodiment, in the first drawing step (t_0 to t_1), the reset drive and the writing drive are performed at all the pixels. In the second drawing step (t_2 or later), however, only image data such as pen input line or character data are sent
10 to the display panel, and data of a previous (original) image as a background image are not read from the graphic memory. Accordingly, the previous image data are not subjected to image composition with the pen input image in the graphic controller. The
15 display panel is driven without resetting in the second drawing step. To a pixel written by pen input, a voltage of the darkest luminance level is applied and at other pixels, a voltage applied thereto is kept at 0 V. No voltage is applied to the pixels to which
20 the pen input is not effected, so that the resultant image is maintained by the memory characteristic of the display panel.

 The driving method of this embodiment includes, similarly as in First Embodiment, the
25 following three steps (1), (2) and (3).

(1) First drawing step

 In this step, image display is performed by a

signal from the first image creation means 2. This drawing step is performed in a period from a time t_0 to a time t_1 shown at (h) of Figure 9. When rewriting of display is effected, resetting is performed prior to writing of a fresh image.

(2) Memory display step

In this step, the finally written image is retained by a memory characteristic of the display panel. This memory display step is performed in a period from the time t_1 to a time t_2 shown at (h). A signal input is terminated at the time t_1 and the display state at the time t_1 is maintained during the period from the time t_1 to that time t_2 .

(3) Second drawing step

In this step, an image is drawn on the display panel with the use of the digitizer 31 and a dedicated pen (stylus) 34, or the displayed image is overwritten with a line or a character. This second drawing step is performed in a period of the time t_2 or later.

Hereinbelow, the second drawing step will be described as a step for rewriting only a pixel, to which the pen input is performed, according to partial scanning. However, similarly as in First Embodiment, the second drawing step may also be performed according to full-screen scanning.

In the first drawing step, the reset drive is

performed in a first field period so as to apply a drain voltage of a polarity opposite to that of a voltage for displaying a writing gradation level on the basis of a source voltage at timing of a gate signal application. In a second field period, the
5 respective source and gate voltages are controlled so as to provide a pixel voltage necessary for writing. Accordingly, writing is performed in two field periods as one frame period.

10 In the second drawing step, in the display panel 1, on the basis of a selection signal inputted from the input terminal 43, driving conditions at each pixel are switched from the reset/writing drive to the writing drive. Further, on the basis of addressing
15 data inputted from the input terminal 43 and partial rewriting image data and synchronizing signal V-sync inputted from the input terminals 41 and 42, drive waveforms are outputted from the scanning signal (gate) line driver 15 and the data signal (source)
20 line driver 16 to display the pen-based inputted line or character image on the display panel.

For example, when the input is performed with respect to solid black pixels 13p, 13q and 13r, different from an ordinary sequential scanning, a
25 writing scanning with no reset is performed by selecting a range of scanning line along which the pixels 13p, 13q and 13r to be driven are present,

i.e., the second gate line (electrode) g2 to the fourth gate line (electrode) g4.

In this case, respective voltages and optical response in the "area 1" are shown in Figures 9(b), 9(c) and 9(d), and those in the "area 2" are shown in Figures 9(e), 9(f) and 9(g). For example, with respect to source lines corresponding to pixels in the "area 2" to which the pen writing is not performed, e.g., the case of selecting the second gate line (electrode) g2, the input voltages to the source line (electrodes) s1 and s3 to s5 are set to 0 V as shown in Figure 9(e). By doing so, it becomes possible to retain a display image in the period of the time t2 or later shown in Figure 9(g) by utilizing the memory characteristic of the electrophoretic display device.

At the pixels in the "area 1" to which the pen writing is performed, the scanning line (electrode) s2 is supplied with a voltage of -15 V of the darkest luminance level at selection timing of the gate line (electrode) g2, whereby the darkest luminance display state is written.

Incidentally, in this embodiment, 0 V is inputted (applied) to non-selection pixels on the data signal driver side. However, e.g., by effecting high-impedance control for the input side or applying a drive voltage smaller than an applied voltage inputted

so as to display a display image at least in the non
rewriting area, the display gradation level is
retained. Accordingly, these may appropriately used
depending on characteristics of the devices having
5 memory characteristic.

When the selection scanning as described
above is performed, a voltage of 15 V is applied to
the pixels to which the pen input writing is
performed, whereby display of the darkest luminance
10 level is effected.

At the pixel areas other than the pixels to
which the pen input writing is performed, the image
held by the memory characteristic of the display
device is continuously displayed as shown in Figure
15 9(g) illustrating the optical response in the "area
2".

In this embodiment, at only the pixel to
which the additional data is written by the pen input
without resetting, the display state is switched
20 (Figures 9(b) to 9(d)). As a result, also, in this
embodiment, the pen input with no inconformity can be
realized in a simple structure.

(Third Embodiment)

In this embodiment, the electrophoretic
25 display apparatus shown in Figures 3 and 4 is driven
in the principally same manner as in First Embodiment
through the first drawing step, the memory display

step, and the second drawing step and the drive waveforms which are identical to those in First Embodiment.

5 The first drawing step is performed by the reset drive and the writing drive. At the time t1, the first drawing step is terminated and after the data line drive voltage becomes 0 V, the immediately previous display image is memory-displayed.

10 When external writing with, e.g., a dedicated pen is performed on the display picture area, the second drawing step is performed.

15 In this embodiment, in the case where the pen input is effected, information from the digitizer 31 is compared and combined with the image information finally stored in the memory of the first image creation means, in the same manner as in First Embodiment.

20 The composite image data is not sent to the display panel immediately but once sent to the graphic controller 401. The graphic controller 401 writes the image data to the VRAM. At a pixel to which rewriting is performed by pen input, image data is set to provide either one of a maximum gradation level (e.g., white) and a minimum gradation level
25 (e.g., black).

 The graphic controller 401 reaches only the full-screen image data or the image data at the

changed pixel from the VRAM and transfer the image data to the read-out display panel 1. On the basis thereof, the display panel 1 effects a full-screen rewriting drive (i.e., whole rewriting drive) or a
5 rewriting drive only at the pixels along the scanning signal line including the changed portion (pixel) (i.e., partial rewriting drive).

Incidentally, in a viewer having a pen input function, a so-called "undo" function of restoring
10 additional information written with the pen input or the like to a previous state.

A driving method employing the "undo" operation will be described below.

As described above, the image information
15 rewritten by the pen input is set to the maximum luminance level (e.g., white) or the minimum luminance level (e.g., black). Accordingly, the previous state at this time is limited the maximum luminance level (e.g., white) or the minimum luminance level (e.g.,
20 black). For this reason, writing for restoring the display state to the previous display state can be performed without using a reset field period for canceling the previous state.

Figure 10 shows a time chart for illustrating
25 a drive sequence at the time of "undo" operation.

Figure 10 shows a gate line drive pulse at (a), a source line drive pulse at (b), a drain voltage

at (c), and optical response at (d), at a pixel to which the pen input is effected.

In the first drawing step, the previous image data is reset to a white level by a positive reset voltage and then written by a negative voltage pulse. 5 After the pen input image is written in the second drawing step, the pen input pixel is placed in the minimum (darkest) luminance level. When the "undo" operation is initiated at the time t_3 , a positive 10 voltage pulse is applied, whereby the state of the pixel is restored from the darkest level to the previous luminance level.

The time chart of in Figure 10 shows the case where the previous state (pen-inputted state) before "undo" operation is of the minimum luminance 15 level. In the case where the previous state is of the maximum luminance level, a polarity of a voltage applied for attaining a previous gradation level is different. Figure 11 shows a time chart in the case 20 where the previous state is of the maximum luminance level.

As described above, at the time of not only the pen input but also the "undo" operation, it is possible to perform the reset-less drive.

25

[INDUSTRIAL APPLICABILITY]

As described hereinabove, according to the

present invention, it is possible to provide a driving method of an electrophoretic display apparatus capable of realizing pen-based input with no inconformity by a simple structure. The electrophoretic display

5 apparatus is applicable to displays having a pen input function, such a wearable PC and electronic note pad.

10

15

20

25

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☐ **FADED TEXT OR DRAWING**
- ☒ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.